PATENT SPECIFICATION

DRAWINGS ATTACHED

1,030,207

1,030,207

Date of Application and filing Complete Specification Aug. 23, 1963.
No. 33575/65.
Application made in United States of America (No. 220531) on Aug. 30, 1962.
Complete Specification Published May 18, 1966.

Index at acceptance:—F2 P(1A9, 1A13, 1B7)

Int. Cl.:—F 06 l

COMPLETE SPECIFICATION

Composite Tubing and Method of Manufacture thereof

ERRATUM

SPECIFICATION No. 1,030,207

Page 1, Heading, Date of Application and Complete Specification Aug. 23, 1963. *for* "No. 33575/65" *read* "No. 33575/63."

THE PATENT OFFICE
24th November 1966

tubing has a high strength and is useful in various applications in for example the earth moving and the spraying equipment fields, wherein relatively high hydraulic pressures are utilized for conveying fluid through oper- [illegible] tubing has [illegible] which stem primarily from the crystalline nature of the nylon resin. First of all, such tubing is somewhat less flexible than what is desirable for pressure [illegible] applications, and secondly, such tubing is subject somewhat to "crimping" which once it has occurred in a length of tubing represents a permanent area of weakness on subsequent flexure of the tubing.

The present invention aims to provide a high strength composite plastic tubing having greater flexibility and resistance to "crimp" [illegible]

accordance with the instant invention;

Figure 2 is a transverse, cross sectional view taken generally along the plane of line 2—2 of Figure 1, looking in the direction of the arrows;

Figure 3 is a more or less diagrammatic top plan view of apparatus for producing the inner tube of the composite tubing of Figures 1 and 2;

Figure 4 is a more or less diagrammatic side elevational view of apparatus for taking the inner tube produced by the apparatus of Figure 3, and applying an adhesive thereto, and then applying, such as by braiding, reinforcing material about such inner tube, and resulting in bonding of the reinforcing material to the inner tube;

Figure 5 is a more or less diagrammatic top plan view of apparatus for taking the inner tube with the reinforcing material adhered

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COMPLETE SPECIFICATION

Composite Tubing and Method of Manufacture thereof

We, SAMUEL MOORE AND COMPANY, a corporation organized and existing under the laws of the State of Ohio, United States of America, of Mantua, Portage County, State of Ohio, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to composite tubing and more particularly to reinforced, composite plastic tubing, for conveying pressurized fluid.

In our United Kingdom Patent Specification No. 930573 there is disclosed a composite plastic tubing comprising an inner tube of nylon, at least one layer of fibrous reinforcing material disposed about the inner tube and forming a reinforcing member therefore, and an outer sheath of nylon covering the reinforcing material. Such a composite nylon tubing has a high strength and is useful in various applications in for example the earth moving and the spraying equipment fields, wherein relatively high hydraulic pressures are utilized for conveying fluid through operating lines. However, this nylon tubing has certain disadvantages which stem primarily from the crystalline nature of the nylon resin.

First of all, such tubing is somewhat less flexible than what is desirable for pressure hoses at least for certain applications, and secondly, such tubing is subject somewhat to "crimping" which once it has occurred in a length of tubing, represents a permanent area of weakness on subsequent flexure of the tubing.

The present invention aims to provide a high strength composite plastic tubing having a greater flexibility and resistance to "crimp" than the nylon tubing just mentioned.

The invention accordingly provides a composite tubing comprising an inner tube of extruded thermoplastic elastomeric polyurethane material, at least one layer of fibrous material disposed about said inner tube and forming a reinforcing member, an elastomeric polyurethane adhesive bonding said reinforcing member to said inner tube, and an outer sheath of extruded thermoplastic elastomeric polyurethane material covering said reinforcing member, said adhesive bonding said outer sheath to said reinforcing member and to said inner tube.

The invention includes also methods of manufacturing such tubing.

The invention will now be further described with reference to the accompanying drawings which illustrate by way of example certain embodiments thereof together with a known tubing for comparison purposes. In the drawings:—

Figure 1 is a partially sectioned and partially cutaway view of a composite tubing in accordance with the instant invention;

Figure 2 is a transverse, cross sectional view taken generally along the plane of line 2—2 of Figure 1, looking in the direction of the arrows;

Figure 3 is a more or less diagrammatic top plan view of apparatus for producing the inner tube of the composite tubing of Figures 1 and 2;

Figure 4 is a more or less diagrammatic side elevational view of apparatus for taking the inner tube produced by the apparatus of Figure 3, and applying an adhesive thereto, and then applying, such as by braiding, reinforcing material about such inner tube, and resulting in bonding of the reinforcing material to the inner tube;

Figure 5 is a more or less diagrammatic top plan view of apparatus for taking the inner tube with the reinforcing material adhered thereto, from a payoff reel, and extruding thereover the outer sheath of elastomeric poly-

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urethane material, to form the bonded composite tubing product of the invention;

Figures 6, 7 and 8 are respectively views of a known composite plastic tubing formed from an inner tube of nylon, intermediate braided reinforcing material, and an outer nylon sheath, and with such tubing being disposed in respectively a straight line or axial condition, a partially bent condition and more fully bent condition;

Figure 6A is a highly magnified sectional illustration of the condition of the layers of the materials forming the composite tubing of Figures 6 to 8 when the latter tubing is in the straight line condition of Figure 6;

Figures 7A and 7B are views similar to that of Figure 6A, but illustrating the condition of the layers when the tubing is in the Figure 7 partially bent condition, with Figure 7A being taken from the top side of the Figure 7 tubing, while Figure 7B is taken from the underside of the Figure 7 tubing;

Figures 8A and 8B are views similar to Figures 7A and 7B, respectively, but illustrate the condition of the layers when the tubing is in the Figure 8 condition;

Figures 9, 10 and 11 are views corresponding to those of Figures 6, 7 and 8, respectively, but showing the same condition of a composite plastic tubing formed in accordance with the present invention; and

Figures 9A, 10A, 10B, 11A and 11B are magnified views of the Figures 9 to 11 tubing, and correspond generally to Figures 6A, 7A, 7B, 8A and 8B, respectively.

Figures 1 and 2 of the drawings show a piece of plastic composite tubing T, comprising an inner tube 10 formed of extruded thermoplastic elastomeric polyurethane, such inner tube being adapted to carry the flow of fluid therethrough. Surrounding the inner tube is a fibrous reinforcing sleeve member 12 comprising a plurality of strands or "yarns" 14 which in the embodiment illustrated have been machine braided about the inner tube, using a regular weave. An elastomeric polyurethane adhesive 15 (formulated as will be described) is utilized, which adhesive encapsulates the strands of the reinforcing material, and bonds the reinforcing sleeve member to the inner tube. Superimposed over the reinforcing sleeve member 12 is an extruded, outer sheath 16 of thermoplastic elastomeric polyurethane, which is bonded to the reinforcing material and to the inner tube by the aforementioned layer of elastomeric adhesive; this arrangement provides a high strength composite tubing possessing very good flexibility and crimp resistance.

The extrudible thermoplastic polyurethane resins which are usable in the composite tubing compounds are chemically the reaction products of a hydroxy terminated polyester with diphenylmethane diisocyanate, to form a prepolymer which is then chain extended with a polyhydroxy compound to produce a cured resin. The proportions of "Texin" used to form the blended polyurethane elastomer for both the inner tube 10 and the outer sheath 16 may be varied over a range of 20% "Texin 480A" and 80% "Texin 355D" to 80% "Texin 480A" and 20% "Texin 355D". A proportion that has been found to be especially satisfactory has been a blend of 60% "Texin 355D" and 40% "Texin 480A".

The properties of "Texin 480A" are generally as follows:

Tensile strength in p.s.i.	7000
Elongation, percent	600
Hardness-Shore	80

The corresponding properties for "Texin 355D" are:

Tensile strength, p.s.i.	4000
Elongation, percent	250
Hardness-Shore	55

The strands or "yarns" of the reinforcing sleeve member 12 are preferably composed of polyester filaments, such as poly (alkylene terephthalate) ester fibre or more specifically poly (ethylene terephthalate) ester fibre, commonly available under the Registered Trade Mark "Dacron", or of polyamide filaments, such as Nylon. The individual strands or "yarns" are preferably of the floss-type with each formed of a substantial plurality of filaments 18 (Figures 6 to 11B) which are movable with respect to one another. Other high-strength fibre materials may be used for the reinforcing sleeve, such as high tenacity rayon. The strands or "yarns" 14 are disposed in tensioned relation about the inner tube, thereby minimizing volumetric expansion of the composite tubing during the conveying of fluids therethrough.

The polyurethane adhesive, which is used for encapsulating the reinforcing braided sleeve member 12, and for bonding the latter to both the inner tube 10 and to the outer sheath 16, preferably has the following approximate composition:

Prepolymer	89.2 to 93.3%
Chain extender	5.6 to 9.8%
Catalyst	1.0 to 1.2%

The preferred prepolymer for the above mentioned adhesive composition is known commercially as "Adiprene L100" ("Adiprene" is a Registered Trade Mark) which is a product of the E.I. Dupont Chemical Corporation.

The preferred chain extender is known commercially as "Moca" and which is again a product of E.I. Dupont Co. This "Moca"

similar effect. Examples of some of such other dibasic acids which could be used as catalysts are oxalic, malonic, succinic, glutaric, sebacic, etc. The adhesive, being a two-part catalyzed system, has a relatively short pot life, and therefore is preferably mixed within a few minutes before application to the hose. Application of the latter adhesive will be hereinafter described in greater detail.

In its final cured state, the adhesive physically encloses or encapsulates the individual strands or "yarns of the sleeve member, and the elasticity and flexibility of the adhesive control the degree of motion and slippage of the filaments.

Another adhesive which may be utilized in the production of the composite plastic tubing of the invention and which gives satisfactory results consists of approximately 65% by weight of "F66", 30% by weight of "Nalco 1718", and approximately 5% tall oil. "F66" is a prepolymer similar in certain respect to "Adiprene L100" but manufactured by the Mobay Chemical Co. "Nalco 1718" is a polyhydroxic compound manufactured by the National Aluminate Co.

In the mixture of the adhesive materials, the prepolymer is actually the basis or backbone of the cured polymer. It is called a prepolymer because it is a partially polymerized material consisting of two monomeric substances. However, its molecular weight is such that it is still in a liquid state and does not resemble a cured plastic. When the chain extender and the catalyst are added to the prepolymer, the length of the chain is increased which in turn increases the molecular weight of the plastic compound such that it becomes a solid having the properties desired. It is believed that a small amount of cross linking between the backbone chains does occur, though the amount of cross linking must be very small or else the polymer would turn into an insoluble and infusible mass without the flexibility and elasticity required to control the slippage of the individual filaments within each strand.

The outer sheath of the composite plastic hose is formed of the same general composition as utilised in the production of the inner tube of the composite hose.

The wall thicknesses of the respective sections of material forming the composite tubing of the invention have been found to be preferably as follows: For a $\frac{3}{8}$ inch internal diameter hose, the wall thickness of the inner tube 10 should preferably be within the range of .030 to .050 inches and with such size of tubing, the preferable thickness of the outer sheath 16 should be within the range of .025 to .040 inches. The approximate overall dimension or thickness of the wall of the composite tubing is preferably from about .090 inches to .125 inches. This thickness, of course, presupposes an integral construction with the various components of the wall held or bonded together by the elastomeric adhesive material 15.

Figure 3 diagrammatically shows apparatus for producing the inner tube 10 of the composite tubing. Such inner tube is formed by extrusion, and the extrusion of such inner tube with its relatively thin wall may present support problems, and therefore an internal air pressure of predetermined value is maintained in the tubing as it is extruded from the cross head 23 of extrusion machine 24.

The extrusion machine may be of a more or less conventional type, but embodying a hopper drier unit 26, and extrusion mechanism 28 which forces the heated polyurethane material out of the die orifice 29 of the head. An internal air pressure control unit (not shown) which is known in the art, may be provided for maintaining the aforementioned air pressure interiorly of the inner tube, as it is extruded from the head. Reference may be had to United States Patent Specification No. 3,159,183, in which there is a disclosure of an air control unit and associated mechanism, for applying internal air pressure to a plastic tube during the extrusion thereof.

From head 23, the length of extruded inner tube is moved through a relatively short water bath 30 for quenching the hot tube, and thus substantially "setting" it and thereby preventing subsequent elongation or stretching. The tube may be taken from the water bath 30 by means of any suitable haul-off device 36, which may be of the known powered caterpillar type, and it is then moved into a second water tank 38 for further cooling. After leaving the bath 38, the tubing is wound upon a reel mechanism 40 of conventional construction.

Referring now to Figure 4, a reel 42 of the extruded elastomeric polyurethane inner tubing 10 is mounted on a payoff stand 44 of conventional type, as for instance illustrated in the aforementioned United States Patent Specification No. 3,159,183; the tubing is passed through an adhesive applicator 46 which, as illustrated in Figure 4, may embody a funnel portion *46a*. Reference may be had to the aforementioned United States patent specification for a more detailed description of a suitable applicator. The tubing may be then passed through a conventional drier unit 48 which for instance, by use of hot air, may expedite the "gelling" of the adhesive material on the inner tube to aid in the "setting" of the adhesive layer 15 on the inner tube. However, the drier unit may be eliminated as it is not absolutely necessary when the adhesive is of the composition above described.

From the drier 48, the adhesive coated inner tube may be passed to a braiding mechanism 50 which may be of any conventional type, many of which are known in the tubing art. After the inner tube has been braided

with one or more layers of reinforcing material, it is wound upon a reel 54 for further handling. The inner tubing, instead of being provided with a braided layer of reinforcing material, could be provided with a served or taped type of reinforcement, it being understood that there are many mechanisms available in the tubing art for applying such taped or served reinforcement to the exterior of tubing. The only requirement is that the taped reinforcement comprise strands or "yarns" of multiple filaments 18, as described above.

By subjecting the tubing to the drier 48 for the correct period of time (which may be relatively short such as approximately 15 seconds to two minutes) between the application of the adhesive to the inner tube and the application of the reinforcing material to the adhesive, the liquid adhesive can be brought to a gel state at the time the reinforcing material is applied over it. The adhesive will reach the fully cured state on merely standing at room temperature for a period of 24 to 72 hours. However, by exposing the composite tubing to an elevated temperature, such as for instance from 150° F. to 250° F. from 8 to 24 hours, the cure may be hastened.

The viscosity of the adhesive during its application to the inner core may be within the range of 1000 to 100,000 centipoises, the preferred range being from 5000 to 2,000 centipoises. The adhesive is applied to the inner tube at a temperature of from 70° F. to 225° F. with a preferred temperature range of 125° F. to 200° F. The adhesive, because of its viscosity, is not absorbed into the strands 14, but encapsulates such strands, and may pass through the interstices between them. After the reinforcing sleeve member has been applied to the inner tube, and before the adhesive material has cured, or in other words relatively shortly after application of the braid 12, the braided and adhesive coated inner tube is taken to an extruder for application of the outer sheath thereto.

Referring to Figure 5, there is shown a payoff stand 60 carrying a reel 54 from which braided tubing is fed through an adhesive applicator mechanism 62, which may be described in connection with Figure 4, and which coats braided tubing, with a liquid polyurethane elastomeric adhesive. From applicator 62 the tubing passes through a conventional, blower operated air drier unit 66.

A tension device 70, which may be of the conventional wheel type, may be provided for maintaining a constant tension on the braided and adhesive coated tubing as it is pulled off the payoff reel 54. The tubing may then be passed into a vacuum apparatus 72 the tubing as it passes through the cross head 73 of extruder mechanism 74, which extruder mechanism is adapted for applying the outer sheath 16 of elastomeric polyurethane material.

Extruder mechanism 74 includes a drier hopper unit 76 for drying the elastomeric polyurethane material prior to extrusion thereof onto the tubing. This pre-drying preferably occurs for a minimum of one hour at approximately 200° F. At head 73 of the extruder mechanism 74, the outer sheath 16 is applied to the tubing and is adhered by the adhesive coating 15 encapsulating the reinforcing sleeve member 12 of the tubing.

From extruder head 73, the sheathed tubing is passed through a water bath 80 which quenches and cools the heated tubing. Haul off mechanism 82, which may be of the caterpillar type, draws the tubing from the water bath 80 and from the extruder head 73.

The tubing is then passed through a conventional marking mechanism 84 which is well known in the art for applying a trademark and/or other identifying indicia to the sheath of the tubing product. The tubing is then wound upon a reel 86 of coiler mechanism 88, and may be stored for subsequent use or shipping. As mentioned above, the adhesive will reach a finally cured state on standing at room temperature for a period of from 24 to 72 hours, or the cure may be hastened by the use of an elevated temperature exposure to the tubing, such as for instance 150° to 250° F. for a period of from 8 to 24 hours.

Once the manufacturing process has been started, it may be a substantially automatic process wherein all of the above-described apparatuses operate continuously. It will be seen, therefore, that even though the various apparatuses have been illustrated and described in more or less sectional groups, comprising first the production of the inner core 10 and then the production of the braided or reinforcing material 12 bonded to the inner core, and then the production of the outer sheath 16 bonded to the reinforcing material of the tubing, the process could be performed in one continuous straight lined arrangement.

Referring now to Figures 6 to 11B inclusive, Figures 6 to 8 and Figures 6A to 8B, show various conditions of a known plastic composite tubing X which is illustrated for the purpose of contrasting it with the tubing according to the present invention. This tubing X comprises an extruded nylon inner tube 90, a braider layer of fibrous reinforcing material 92 disposed in generally tensioned relation around the inner tube, and an outer sheath 94 of extruded nylon material encasing the inner tube and reinforcing material. This tubing is disclosed in our above-mentioned United

the nylon inner tube 90 and of the sheath, by means of a chemical solvent for nylon. Some such materials which may function in this capacity are phenol, various cresols, cresylic acid, or solutions or resorcinol. These materials create a generally soft, sticky condition on the surface of the nylon, and when the braid is applied under tension, it tends to bury itself into the confronting soft surface layer of nylon, which actually is nylon in solution, and when the solvent evaporates there is a firm joining of the braid to the surface of the nylon. However, the braid is generally immobilized under these conditions, and it is not free to flex in tension or compression when the tubing is bent, since the dissolved nylon has generally penetrated the strands 14 and substantially immobilized the filaments thereof.

As can be seen from Figure 6A, the individual strands or "yarns" 14 of strengthening material comprise a multitude of filaments 18, such as for instance a 1100 denier Dacron yarn; these strands or "yarns" 14 are effectively embedded in both the inner tube 90 and the outer sheath 94 due to the action of the solvent. Upon partial bending of such a composite tubing, as shown, for instance, in Figures 7, 7A and 7B, the strands on the upper and undersides of the tubing, are put under tension and compression respectively, and the cross-sections of these strands may become distorted as shown; since the outer filaments of each yarn are embedded in intimate contact with the confronting crystalline nylon material, and the filaments are generally immobilized against movement with respect to one another, such filaments are stretched and distorted out of normal position with respect to the other filaments of the respective yarn or strand, and the hose assumes a slight oval shape in cross section. This is primarily because the filaments of each strand are not readily movable, but instead are immobilized by being embedded in the adjacent nylon material, and the filaments are immobilized by the penetration of the solvent into the strands.

A greater bend of the tubing X is shown in Figures 8, 8A and 8B; because the filaments 18 of strands 14 have substantially no longitudinal slide with respect to one another, and the fused structure prevents compression of the strands or yarn without inducing a linear pull with regard to the inner tube 90, a crimping force is induced in the tubing, and the latter crimps, as at 100, to cause a more or less permanent area of creasing to be induced in the tubing. At this area future failure of the tubing may occur.

Now referring to Figures 9 to 11B, in the straight condition of a piece of tubing of the present invention, it will be seen that the "yarns" or strands 14 of the braided material are of generally circular configuration, and are completely encapsulated in the elastomeric polyurethane adhesive layer 15. Upon partial bending of the elastic tubing, as shown in Figures 10, 10A and 10B, the "yarn" cross sections become longitudinal ellipses on the upper side of the hose (Figure 10A), as the filaments 18 move in an orderly manner with regard to one another due to the non-penetration of the adhesive and also to the elasticity of the polyurethane adhesive layer 15 and the elasticity of the inner tube 10 and outer sheath 16; and on the lower side, such "yarn" cross sections form a generally vertically elliptical condition (Figure 10B), due to compression forces on that side. Since the strands or "yarns" 14 are encapsulated or embedded in the elastomeric adhesive, and the adhesive gives with the compression and tension of the tubing, and the filaments of each strand or "yarn" 14 are generally free to move with respect to one another, the strands or "yarns" 14 in an orderly manner absorb the forces applied to the tubing wall.

Upon greater flexure of the tubing, as shown in Figure 11, the filaments slide in a more or less circumferential direction with respect to the core tubing, and longitudinally with regard to the respective strand, and thus form greater elliptical configurations of cross-section, as shown in the enlarged sections, (Figures 11A and 11B) of such view, without crimping occurring.

Tests have been performed on the composite tubing of the invention as compared to the composite plastic tubing X. Samples of one-quarter inch and three-eights inch internal diameter of each of the two forms of tubing were supported in a flexing test device, and each sample was bent to U-shape having approximately one and a half inch radius. With the composite tubing X a force of 12 to 14 pounds was required to bend the one-quarter inch internal diameter sample. The same size of hose in the polyurethane construction of the present application required merely a force of 5 to 7 pounds. In a three-eights inch internal diameter hose of the tubing X, a force of 22 to 25 pounds was required. With the polyurethane tubing of the present invention, only 14 to 16 pounds of force was required. It will be seen therefore that the tubing of the present invention has considerably greater flexibility as compared to composite plastic tubing X.

Also, the crimp resistance of the tubing of the present invention was compared with that of the above described nylon construction, and it was found that in a six inch long piece of the one-quarter inch internal diameter nylon tubing, which was bent into a U, a kink or crimp appeared in the tubing upon movement of the ends of the tubing within three inches of one another. In one-quarter inch internal diameter polyurethane tubing of the present invention, no kinks whatsoever appeared in

the tubing even when the ends were bent into contact.

The notch sensitivity of the tubing of the present invention is much lower than that of, for instance, the composite nylon tubing above-described, because nylon is extremely sensitive to notching, especially when dry. Tests comparing the burst strength of the polyurethane tubing of the present invention with that of the nylon tubing showed them to be about equal. It will be seen, therefore, that the tubing of the present application while possessing such greater flexibility and resistance to crimp than the nylon tubing described, has the same strength characteristics as the nylon tubing.

WHAT WE CLAIM IS:—

1. A composite tubing comprising an inner tube of extruded thermoplastic elastomeric polyurethane material, at least one layer of fibrous material disposed about said inner tube and forming a reinforcing member, an elastomeric polyurethane adhesive bonding said reinforcing member to said inner tube, and an outer sheath of extruded thermoplastic elastomeric polyurethane material covering said reinforcing member, said adhesive bonding said outer sheath to said reinforcing member and to said inner tube.

2. A composite tubing comprising an inner tube of extruded thermoplastic elastomeric polyurethane material, a plurality of strands disposed about the inner tube and forming a reinforcing member therefor each strand including a multiplicity of separate filaments, an elastomeric polyurethane adhesive bonding said reinforcing member to said inner tube, and an outer sheath of extruded thermoplastic elastomeric polyurethane covering said reinforcing member, said adhesive bonding said outer sheath to said reinforcing member and to said inner tube and encapsulating the strands while permitting controlled movement of inner filaments of each strand within its respective adhesive envelope.

3. A composite tubing as claimed in Claim 1 or Claim 2, wherein said adhesive is formed from a prepolymer, a chain extender, and a reaction catalyst.

4. A composite tubing as claimed in Claim 3, wherein the prepolymer, chain extender and reaction catalyst form by weight respectively 89.2 to 93.3%, 5.6 to 9.8%, and 1.0 to 1.2% of the adhesive.

5. A composite tubing as claimed in any of the preceding claims, wherein said strands are of a floss-type.

6. A composite tubing as claimed in Claim 5, wherein said strands are formed of polyester filaments.

7. A composite tubing as claimed in Claim 5, wherein said strands are formed of polyamide filaments.

8. A composite tubing as claimed in any of the preceding claims, wherein the wall thicknesses of said inner tube and said outer sheath are approximately equal.

9. A composite tubing as claimed in any of the preceding claims, wherein the wall thickness of said inner tube is within the range of .03 to .050 inch and the wall thickness of said outer sheath is within the range of .025 to .040 inch, and the composite wall thickness of said tubing is within the range of .090 to .125 inch.

10. A method of making a composite tubing as claimed in Claim 1, or in Claim 2, comprising the steps of forming an inner tube of extruded thermoplastic elastomeric polyurethane material, applying a liquid layer of elastomeric polyurethane adhesive to the inner tube, causing the adhesive layer to gel, applying a layer of fibrous material about the inner tube and upon the gelled adhesive layer to form a reinforcing member which is encapsulated in the adhesive and thereby bonded to the inner tube, and forming an outer sheath of extruded thermoplastic elastomeric polyurethane material about the reinforcing member with the adhesive bonding said outer sheath to said reinforcing member and said inner tube.

11. A method according to Claim 10, wherein a further layer of liquid adhesive is applied to the reinforcing member and wherein the further layer is caused to gel and wherein the outer sheath is extruded over said gelled further layer member.

12. A method according to Claim 10 or to Claim 11, wherein fluid pressure is admitted into the interior of the inner tube under pressure whereby to keep it in non-collapsed condition during extrusion.

13. The composite tubing herein described with reference to Figures 1 and 2 of the accompanying drawings.

14. The method of making composite tubing herein described with reference to Figures 3 to 5 of the accompanying drawings.

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Fig. I

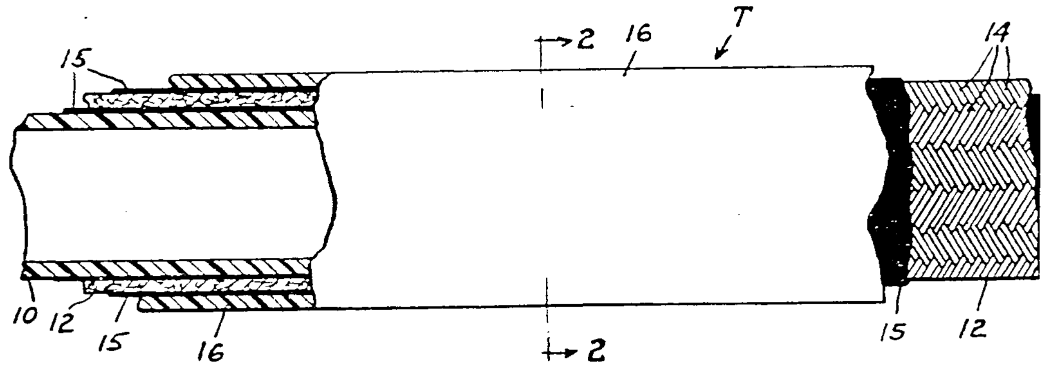
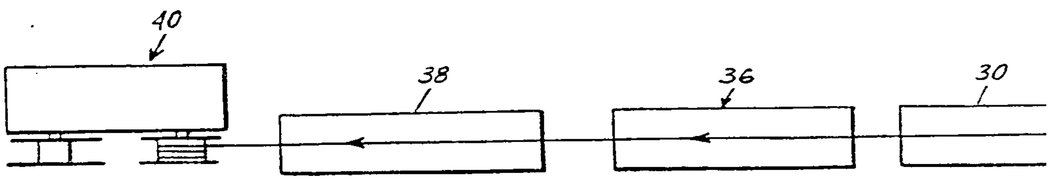


Fig. 3



1030207 COMPLETE SPECIFICATION

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Sheet 1

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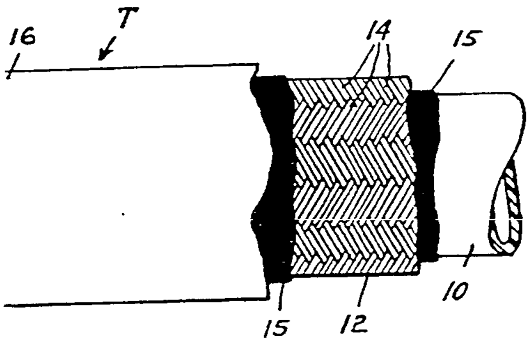
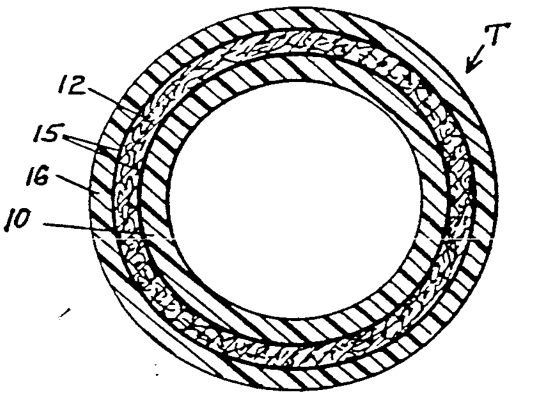


Fig. 2



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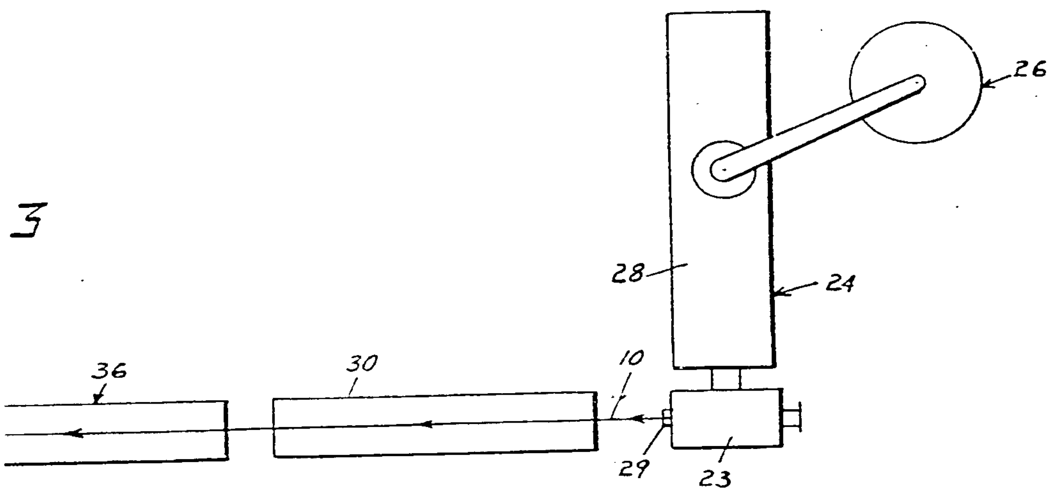

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Sheet 1

Fig. 1

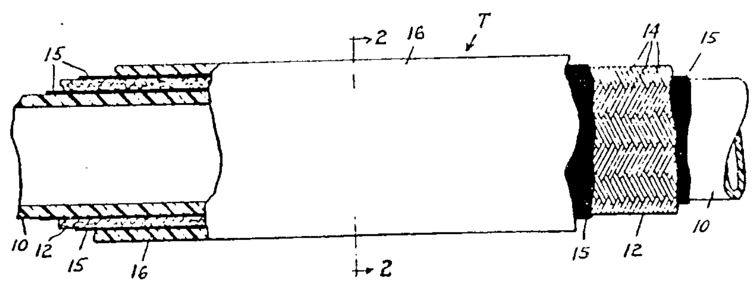


Fig. 2

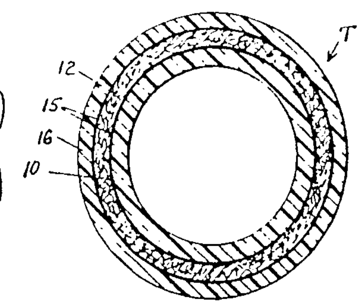
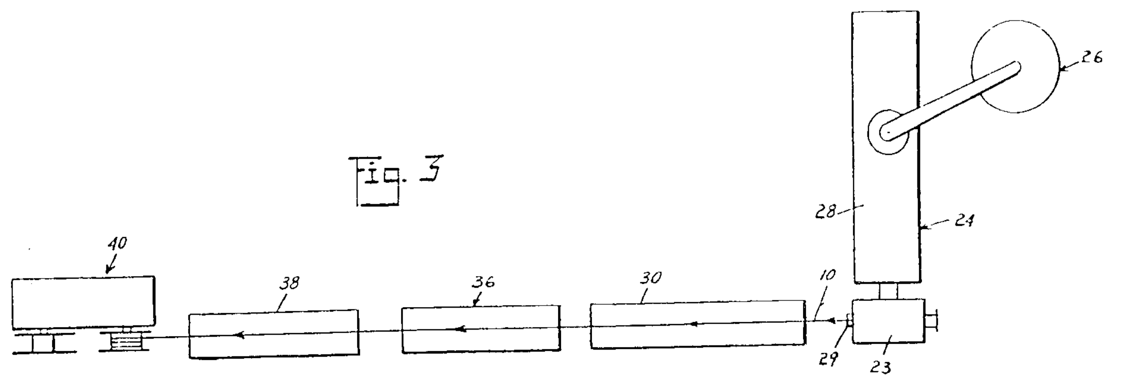


Fig. 3



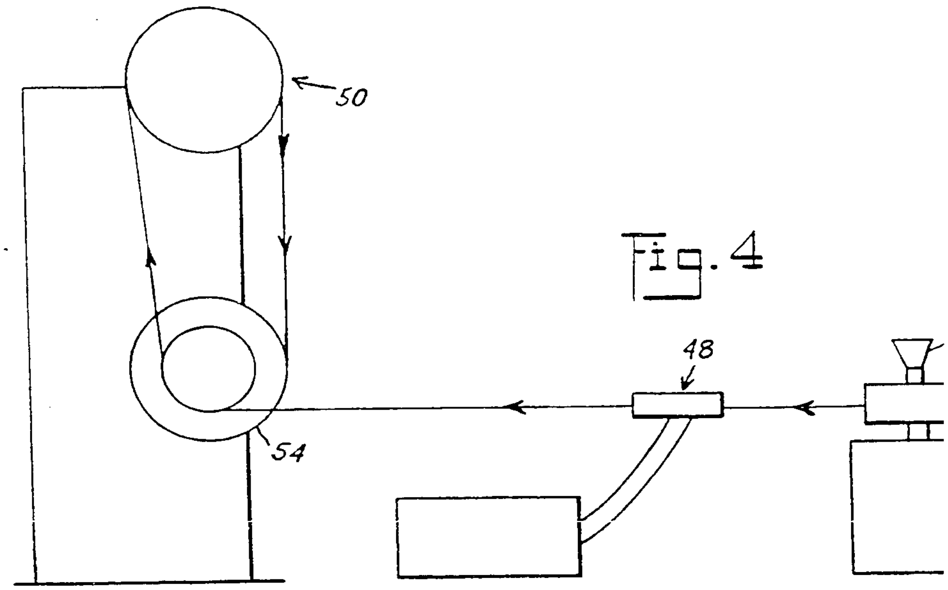


Fig. 4

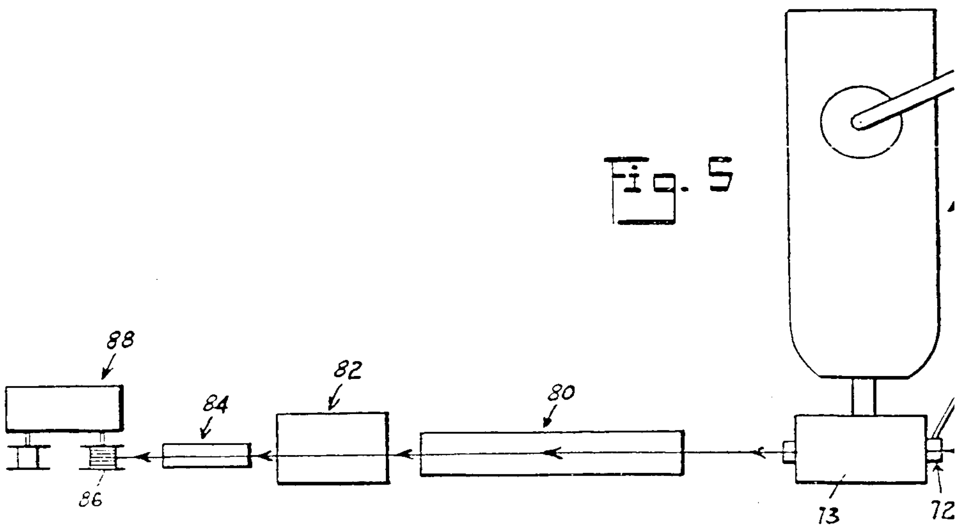


Fig. 5

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Sheet 2

Fig. 4

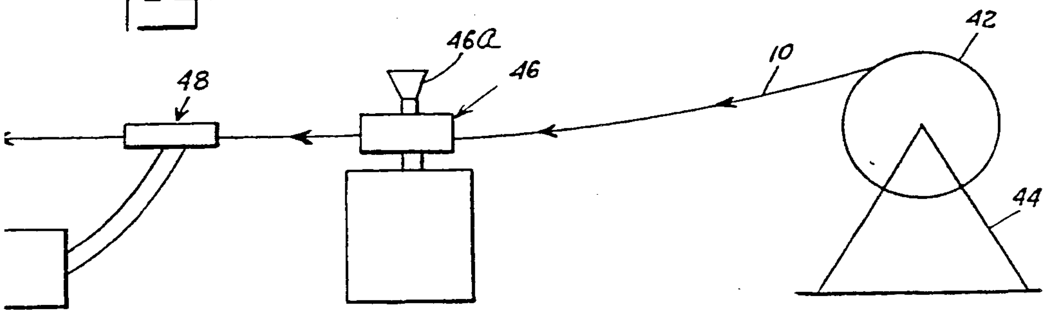
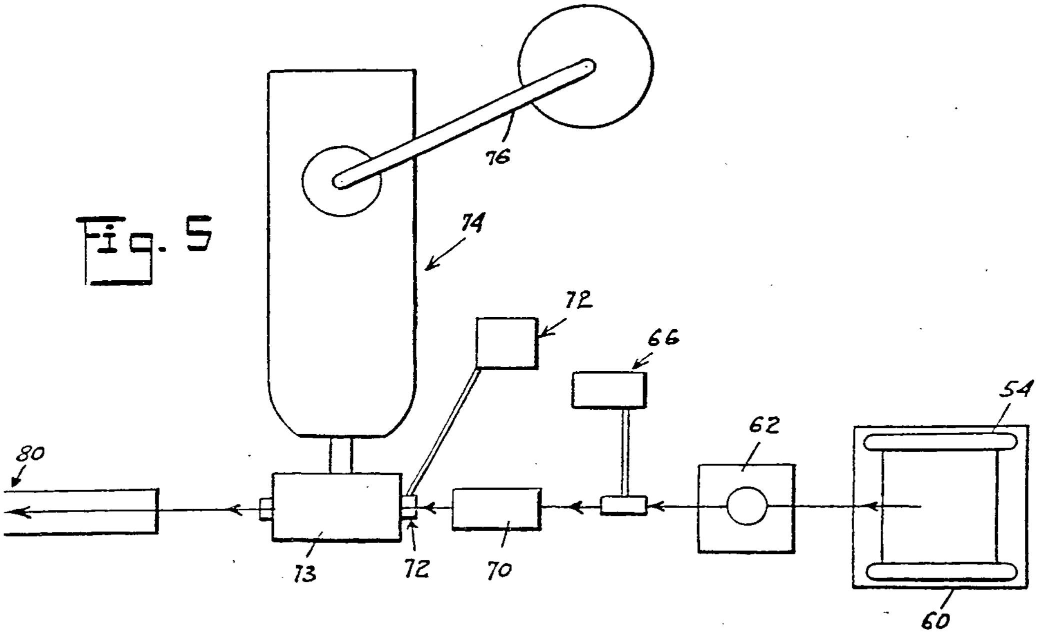


Fig. 5



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3 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 2

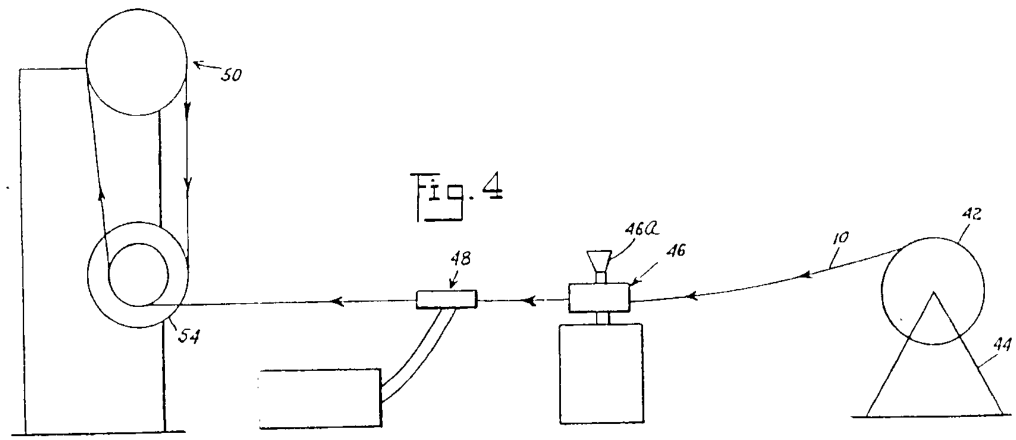


Fig. 4

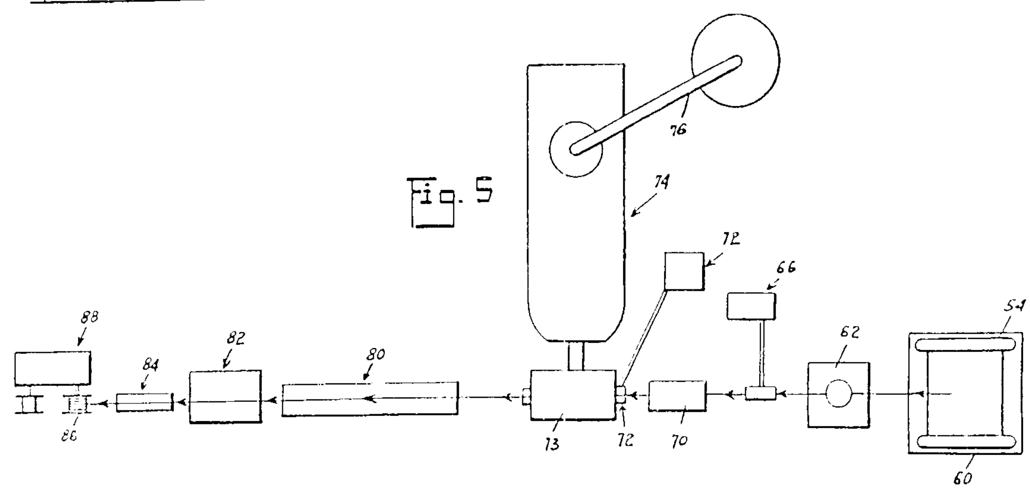


Fig. 5

Fig. 6

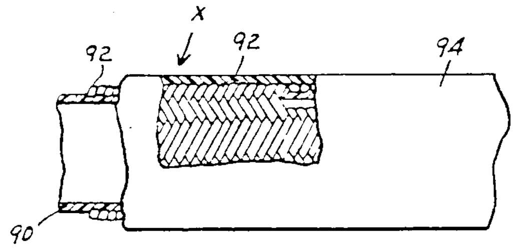


Fig. 6A

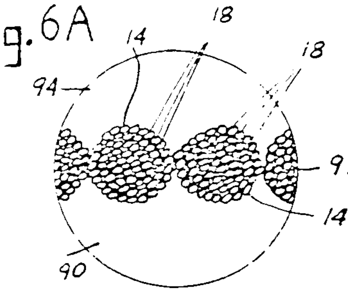


Fig. 7

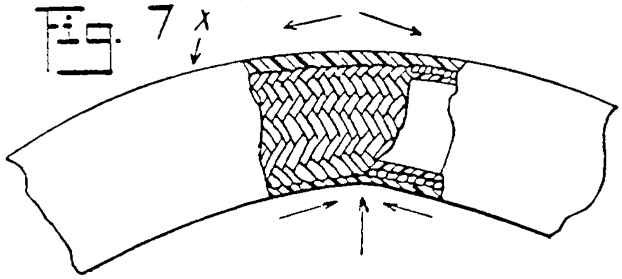


Fig. 7A

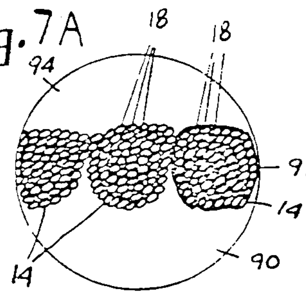


Fig. 7B

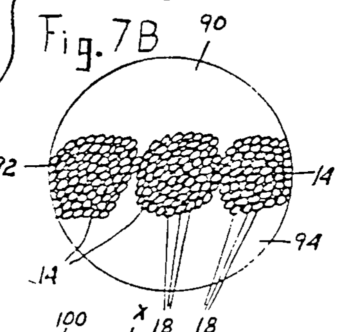
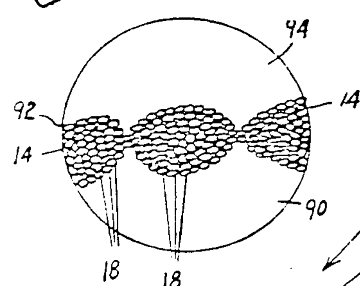


Fig. 8A



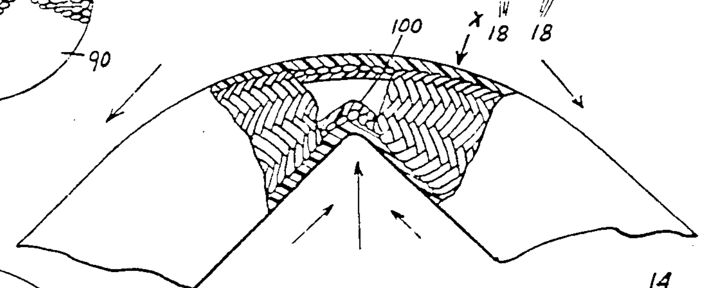
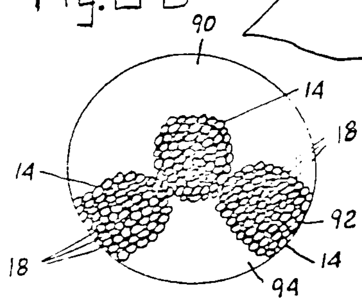
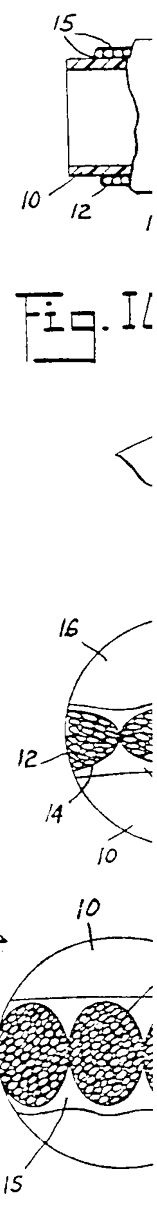


Fig. 8

Fig. 8B





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Sheet 3

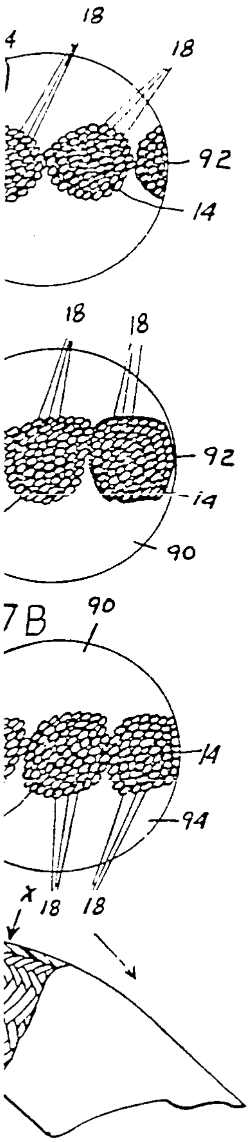


Fig. 9

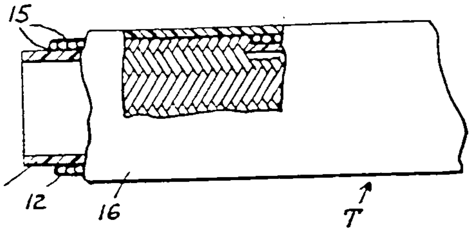


Fig. 9A

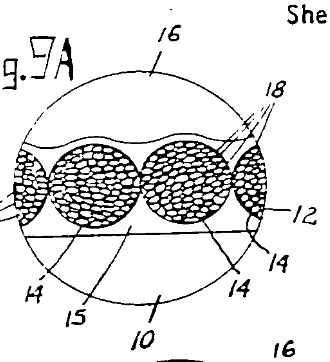


Fig. 10A

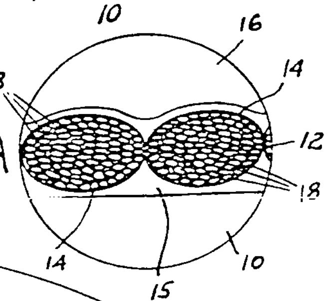


Fig. 10

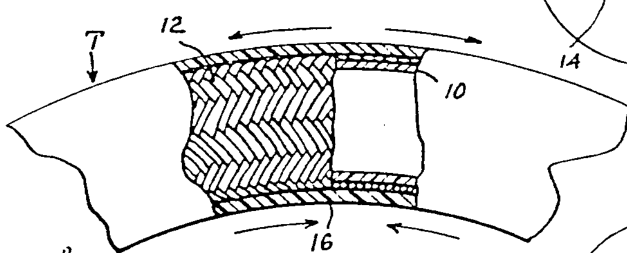


Fig. 11A

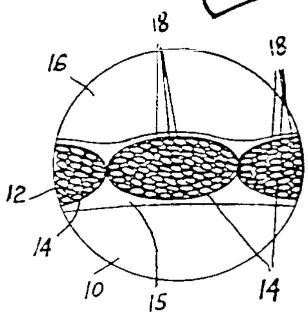
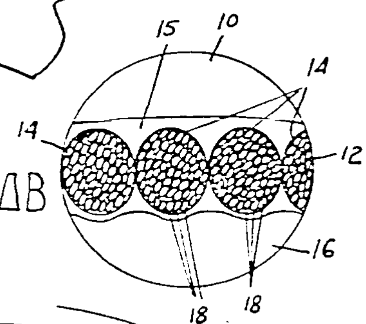


Fig. 10B



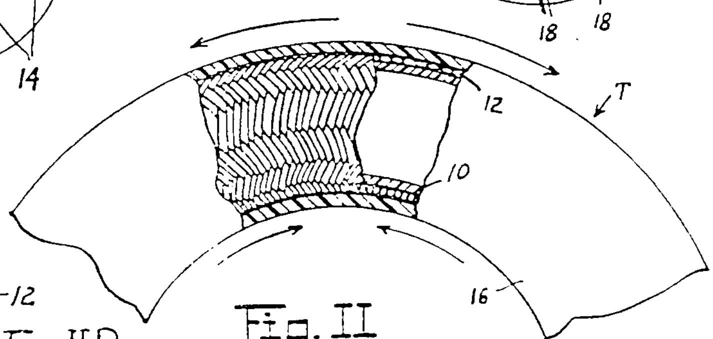


Fig. 11

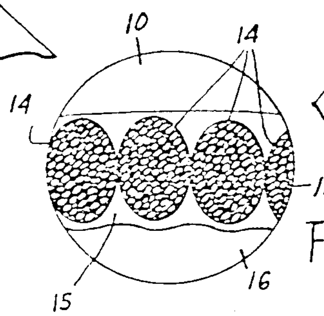


Fig. 11B

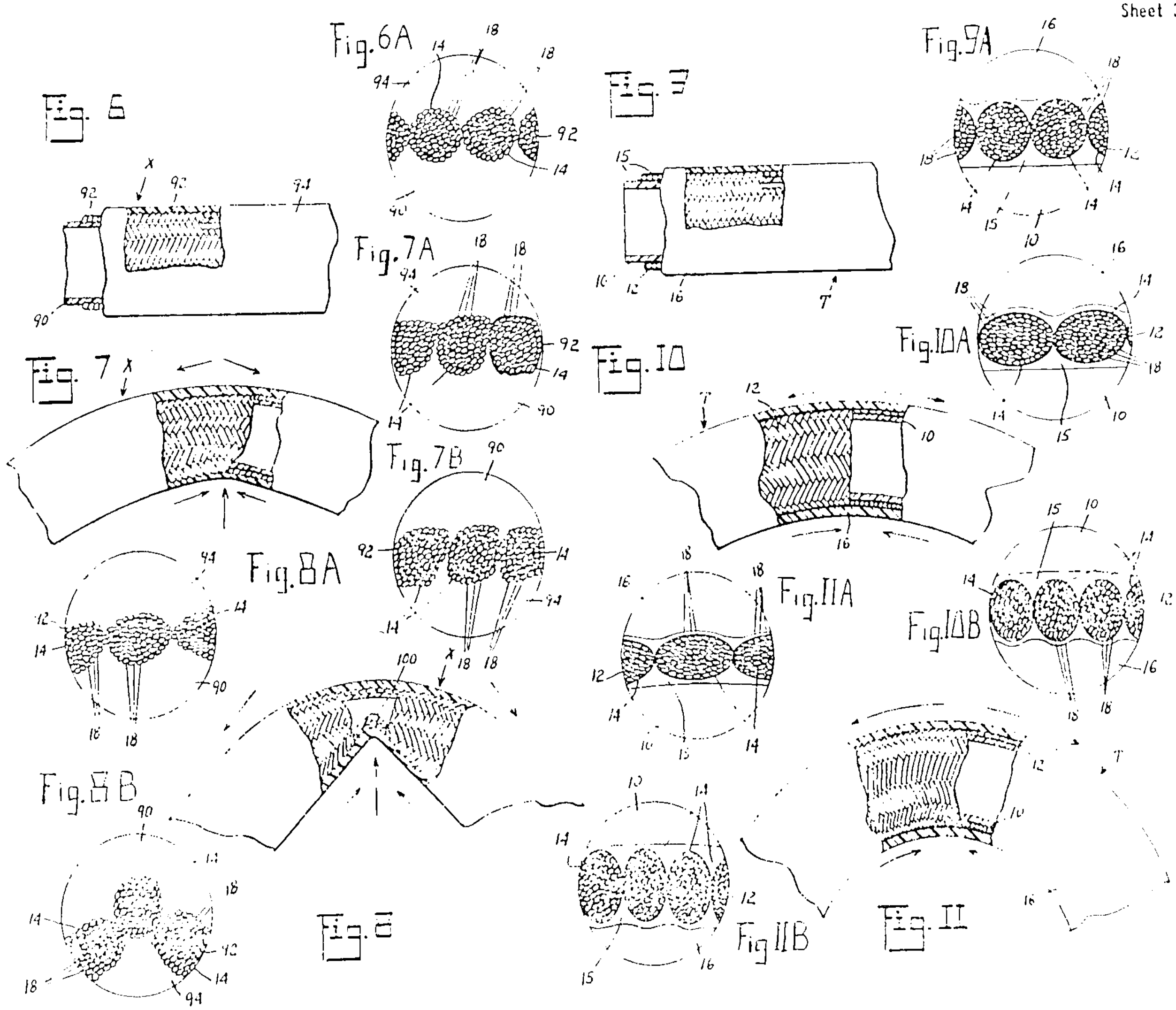


Fig. 6
Fig. 6A
Fig. 7
Fig. 7A
Fig. 7B
Fig. 8
Fig. 8A
Fig. 8B
Fig. 9
Fig. 9A
Fig. 10
Fig. 10A
Fig. 10B
Fig. 11
Fig. 11A
Fig. 11B